10-3.__ FIBER OPTIC GLOSSRY

Breakout.--The cable "breakout" is produced by (1) removing the jacket just beyond the last tie-wrap point, (2) exposing 3 to 6 feet of the cable buffers, aramid strength yarn and central fiberglass strength member, and (3) cutting aramid yarn, central strength member and the buffer tubes to expose the individual glass fibers for splicing or connection to the appropriate device.

Connector.--A mechanical device used to align and join two fibers together to provide a means for attaching to and decoupling from a transmitter, receiver, or another fiber (i.e., patch panel).

Connectorized.--A term that describes the termination point of a fiber after connectors have been affixed.

Connector Module Housing (CMH).--A patch panel used in the FDU to terminate singlemode fibers with most common connector types. It may include a jumper storage shelf and a hinged door.

Couplers.--Couplers are devices which mate two fiber optic connectors to facilitate the transition of optical light signals from one connector into another. Couplers may also be referred to as: adapters, feed-throughs, and barrels. They are normally located within FDUs mounted in panels. They may also be used unmounted, to join two simplex fiber runs.

End-to-End Loss —The maximum permissible end-to-end system attenuation is the total loss in a given link. This loss could be the actual measured loss, or calculated using typical (or specified) values. A designer should use typical values to calculate the end-to-end loss for a proposed link. This number will determine the amount of optical power (in dB) needed to meet the System Performance Margin.

Fan Out Termination —Permits the branching of fibers contained in an optical cable into individual cables and can be done at field locations; thus, allowing the cables to be connectorized or terminated per system requirements. A kit provides pull-out protection for individual bare fibers to support termination. It provides three layers of protection consisting of a Teflon inner tube, a dielectric strength member, and an outer protective PVC jacket.

FBC.--Fiber Backbone Cable.

Fiber Distribution Unit (FDU).—.

An rack mountable enclosure containing both a Connector Module Housing (CMH) and a Splice Module Housing (SMH).

Fiber Storage Enclosure (FSE).--Designed for holding excess cable slack for protection. The FSE allows the user flexibility in equipment location and the ability to pull cable back for resplicing.

F/O.--Fiber optic.

FOIP.--Fiber optic inside plant cable.

FOOP.--Fiber optic outside plant cable.

FOTP.--Fiber optic test procedure(s) as defined by EIA/TIA standards.

FPC.--Fiber Pigtail Cable

FTC.--Fiber Trunkline Cable

Light Source.--A portable fiber optic test equipment that, inconjunction with a power meter, is used to perform end-to-end attenuation testing. It contains a stabilized light source operating at the designed wavelength of the system under test. It also couples light from the source into the fiber to be received at the far end by the receiver.

Link.--A passive section of the system, the ends of which are connectorized. A link may include splices and couplers. For example, a video data link may be from video F/O transmitter to video F/O receiver.

Link Loss Budget.--A calculation of the overall permissible attenuation from the fiber optic transmitter (source) to the fiber optic receiver (detector).

Loose Tube Cable.--Type of cable construction in which fibers are placed in buffer tubes to isolate them from outside forces (stress). A flooding compound or material is applied to the interstitial cable core to prevent water migration and penetration. This type of cable is primarily for outdoor applications.

Mid-span Access Method —Description of a procedure in which fibers from a single buffer tube are accessed and spliced to an adjoining cable without cutting the unused fibers in the buffer tube, or disturbing the remaining buffer tubes in the cable.

MMFO —Multimode Fiber Optic Cable.

Optical Time Domain Reflectometer (OTDR).--A fiber optic test equipment (similar in appearance to an oscilloscope) that is used to measure the total amount of power loss between two points and over the corresponding distance. It provides a visual and printed display of the relative location of system components such as fiber sections, splices and connectors as well as the losses that are attributed to each component and or defects in the fiber.

Patch cord.--A short jumper used to join two Connector Module Housing (CMH) couplers, and or a CMH and an active optical electronic device.

Pigtail.--Relatively short length of fiber optic cable that is connectorized on only one end. All pigtails shall be tight buffer cable.

Power Meter.--A portable fiber optic test equipment that, when coupled with a light source, is used to perform end-to-end attenuation testing. It contains a detector that is sensitive to light at the designed wavelength of the system under test. Its display indicates the amount of power injected by the light source that arrives at the receiving end of the link.

Segment.--A section of fiber optic cable that is not connected to any active device and may or may not have splices per the design.

SMFO.—Singlemode Fiber Optic Cable.

Splice.--The permanent joining of fiber ends to identical or similar fibers.

Splice Enclosure.--An environmentally sealed container used to organize and protect splice trays. The container allows splitting or routing of fiber cables from and to multiple locations.

Splice Module Housing (SMH).--Stores splice trays as well as pigtails and short cable lengths.

Splice Tray.--A container used to organize and protect spliced fibers.

Splice Vault.—An underground container used to house excess cable and splice enclosures.

System Performance Margin.—A calculation of the overall "End to End" permissible attenuation from the fiber optic transmitter (source) to the fiber optic receiver (detector). The system performance margin should be at least 6 dB. This includes the difference between the active component link loss budget, the passive cable attenuation (total fiber loss) and the total connector/splice loss.

Tight Buffer Cable.--Type of non-breakout cable construction where each glass fiber is tightly buffered (directly coated) with a protective thermoplastic coating to 900 μm with the exception of the protective thermoplastic coating. The tight buffer cable shall meet all the characteristics of the fiber in the fiber optic outside plant cable specified elsewhere in these specifications.

10-3.__ FIBER OPTIC CABLE

GENERAL.--Each fiber optic cable for this project shall be all dielectric, gel filled, duct type, with loose buffer tubes construction with a maximum outside diameter of 0.55" and shall conform to these special provisions. Cables shall contain singlemode (SM) dual-window (1310 nm and 1550 nm) fibers with the numbers described below and as shown on the plans:

Fiber trunkline cable (FTC)	72 SM fibers
Fiber backbone cable (FBC)	12 SM fibers
Fiber pigtail cable (FPC)	12 SM fibers

The optical fibers shall be contained within loose buffer tubes. The loose buffer tubes shall be stranded around an all dielectric central member. Aramid yarn shall be used as a primary strength member, and a polyethylene outside jacket shall provide for overall protection.

All F/O cable of each specific type shall be from the same manufacturer, who is regularly engaged in the production of this material.

The cable shall be qualified as compliant with Chapter XV11, Title 7, Part 1755.900 of the Code of Federal Regulations, "REA Specification for Filled Fiber Optic Cables"

FIBER CHARACTERISTICS.--Each optical fiber shall be made of glass and consists of a doped silica core surrounded by concentric silica cladding. All fibers in the buffer tube shall be usable fibers, and shall be sufficiently free of surface imperfections and inclusions to meet the optical, mechanical, and environmental requirements of these specifications. The required fiber grade shall reflect the maximum individual fiber attenuation, to guarantee the required performance of each and every fiber in the cable.

The coating shall be a dual layered, UV cured acrylate and shall be mechanically strippable without damaging the fiber.

The cable shall comply with the optical and mechanical requirements over an operating temperature range of -40°C to +70°C. The cable shall be tested in accordance with EIA-455-3A (FOTP-3), "Procedure to Measure Temperature Cycling Effects on Optical Fiber, Optical Cable, and Other Passive Fiber Optic Components." The change in attenuation at extreme operational temperatures (-40°C to +70°C) for singlemode fiber shall not be greater than 0.20 dB/km, with 80 percent of the measured values no greater than 0.10 dB/km. The singlemode fiber measurement is made at 1550 nm.

For all fibers the attenuation specification shall be a maximum attenuation for each fiber over the entire operating temperature range of the cable.

Singlemode fibers within the finished cable shall meet the requirements in the following table:

Fiber Characteristics Table

Parameters	Characteristic
Type	Step Index
Core diameter	8.3 µm (nominal)
Cladding diameter	125 µm ±1.0 µm
Core to Cladding Offset	≤1.0 µm
Coating Diameter	250 µm ±15 µm
Cladding Non-circularity defined as: [1-(min. cladding dia ÷max. cladding dia.)]x100	≤2.0%
Proof/Tensile Test	50 kpsi, min.
Attenuation: @1310 nm @1550 nm	 ≤0.4 dB/km ≤0.4 dB/km
Attenuation at the Water Peak	≤2.1 dB/km @ 1383 ±3 nm
Bandwidth: @ 850 nm @1310 nm (SM)	 N/A N/A
Chromatic Dispersion: Zero Dispersion Wavelength Zero Dispersion Slope	 1301.5 to 1321.5 nm ≤0.092 ps/(nm^2∗km)
Maximum Dispersion:	≤3.3 ps/(nm∗km) for 1285 - 1330 nm <18 ps/(nm∗km) for 1550 nm
Cut-Off Wavelength	<1250 nm
Mode Field Diameter (Petermann II)	9.3 ±0.5 µm at 1300 nm 10.5 ±1.0 µm at 1550 nm

COLOR CODING.--In buffer tubes containing multiple fibers, each fiber shall be distinguishable from others in the same tube by means of color coding according to the following:

1. Blue (BL)	7. Red (RD)
2. Orange (OR)	8. Black (BK)
3. Green (GR)	9. Yellow (YL)
4. Brown (BR)	10. Violet (VL)
5. Slate (SL)	11. Rose (RS)
6. White (WT)	12. Aqua (AQ)

Buffer tubes containing fibers shall also be color coded with distinct and recognizable colors according to the following:

1. Blue (BL)
2. Orange (OR)
3. Green (GR)
4. Brown (BR)
5. Slate (SL)
6. White (WT)

The colors shall be targeted in accordance with the Munsell color shades and shall meet EIA/TIA-598 "Color Coding of Fiber Optic Cables."

The color formulation shall be compatible with the fiber coating and the buffer tube filling compound, and be heat stable. It shall not fade or smear or be susceptible to migration and it shall not affect the transmission characteristics of the optical fibers and shall not cause fibers to stick together.

CABLE CONSTRUCTION.--The fiber optic cable shall consist of, but not be limited to, the following components:

1. Buffer tubes
2. Central member
3. Filler rods
4. Stranding
5. Core and cable flooding
6. Tensile strength member
7. Ripcord
8. Outer jacket

Buffer tubes.--Clearance shall be provided in the loose buffer tubes between the fibers and the inside of the tube to allow for expansion without constraining the fiber. The fibers shall be loose or suspended within the tubes. The fibers shall not adhere to the inside of the buffer tube. Each buffer tube shall contain up to 12 fibers.

The loose buffer tubes shall be extruded from a material having a coefficient of friction sufficiently low to allow free movement of the fibers. The material shall be tough and abrasion resistant to provide mechanical and environmental protection of the fibers, yet designed to permit safe intentional "scoring" and breakout, without damaging or degrading the internal fibers.

Buffer tube shall contain a water-swellable yarn or a homogeneous hydrocarbon-based gel with anti-oxidant additives for water migration resistance. The filling compound shall be non-toxic and dermatologically safe to exposed skin. It shall be chemically and mechanically compatible with all cable components, non-nutritive to fungus, non-hygroscopic and electrically non-conductive. The filling compound shall be free from dirt and foreign matter and shall be readily removable with conventional nontoxic solvents.

Buffer tubes shall be stranded around a central member by a method that will prevent stress on the fibers when the cable jacket is placed under strain, such as the reverse oscillation stranding process.

Central Member.--The central member which functions as an anti-buckling element shall be a glass reinforced plastic rod with similar expansion and contraction characteristics as the optical fibers and buffer tubes. A linear overcoat of Low Density Polyethylene shall be applied to the central member to achieve the optimum diameter to provide the proper spacing between buffer tubes during stranding.

Filler rods.--Filler rods may be included in the cable to maintain the symmetry of the cable cross-section. Filler rods shall be solid medium or high density polyethylene. The diameter of filler rods shall be the same as the outer diameter of the buffer tubes.

Stranding.--Completed buffer tubes shall be stranded around the overcoated central member using stranding methods, lay lengths and positioning such that the cable shall meet mechanical, environmental and performance specifications. A polyester binding shall be applied over the stranded buffer tubes to hold them in place. Binders shall be applied using tension sufficient to secure the buffer tubes to the central member without crushing the buffer tubes. The binders shall be non-hygroscopic, non-wicking (or rendered so by the flooding compound), and dielectric with low shrinkage.

Core and Cable Flooding.--The cable core interstices shall be filled with a polyolefin based compound to prevent water ingress and migration. The flooding compound shall be homogeneous, non-hygroscopic, electrically non-conductive, and non-nutritive to fungus. The compound shall also be nontoxic, dermatologically safe and compatible with all other cable components.

Tensile Strength Member.--Tensile strength shall be provided by high tensile strength aramid yarns or fiberglass which shall be helically stranded evenly around the cable core and shall not adhere to other cable components.

Ripcord.--The cable shall contain at least one ripcord under the jacket for easy sheath removal.

Outer jacket.--The jacket shall be free of holes, splits, and blisters and shall be medium or high density polyethylene (PE), or medium density cross-linked polyethylene with minimum nominal jacket thickness of 1 mm ±76 µm. Jacketing material shall be applied directly over the tensile strength members and flooding compound and shall not adhere to the aramid strength material. The polyethylene shall contain carbon black to provide ultraviolet light protection and shall not promote the growth of fungus.

The jacket or sheath shall be marked with the manufacturer's name, the words "Optical Cable", the number of fibers, "SM", year of manufacture, and sequential measurement markings every meter. The actual length of the cable shall be within -0/+1 percent of the length marking. The marking shall be in a contrasting color to the cable jacket. The height of the marking shall be approximately 2.5 mm.

GENERAL CABLE PERFORMANCE SPECIFICATIONS.--The F/O cable shall withstand water penetration when tested with a 3 feet static head or equivalent continuous pressure applied at one end of a 3 feet length of filled cable for one hour. No water shall leak through the open cable end. Testing shall be done in accordance with EIA-455-82 (FOTP-82), "Fluid Penetration Test for Fluid-Blocked Fiber Optic Cable."

A representative sample of cable shall be tested in accordance with EIA-455-81A, "Compound Flow (Drip) Test for Filled Fiber Optic Cable." The test sample shall be prepared in accordance with Method A. The cable shall exhibit no flow (drip or leak) at 80°C as defined in the test method.

Crush resistance of the finished F/O cables shall be 115 lbs/in applied uniformly over the length of the cable without showing evidence of cracking or splitting when tested in accordance with EIA-455-41 (FOTP-41) "Compressive Loading Resistance of Fiber Optic Cables." The average increase in attenuation for the fibers shall be ≤0.10 dB at 1550 nm for a cable subjected to this load. The cable shall not exhibit any measurable increase in attenuation after removal of load. Testing shall be in accordance with EIA-455-41 (FOTP-41), except that the load shall be applied at the rate of 0.12" to 0.74" per minute and maintained for 10 minutes.

The cable shall withstand 25 cycles of mechanical flexing at a rate of 30 ±1 cycles/minute. The average increase in attenuation for the fibers shall be ≤0.20 dB at 1550 nm at the completion of the test. Outer cable jacket cracking or splitting observed under 10x magnification shall constitute failure. The test shall be conducted in accordance with EIA-455-104 (FOTP-104), "Fiber Optic Cable Cyclic Flexing Test," with the sheave diameter a maximum of 20 times the outside diameter of the cable. The cable shall be tested in accordance with Test Conditions I and II of (FOTP-104).

Impact testing shall be conducted in accordance with EIA-455-25 (FOTP-25) "Impact Testing of Fiber Optic Cables and Cable Assemblies." The cable shall withstand 20 impact cycles. The average increase in attenuation for the fibers shall be ≤0.20 dB at 1550 nm. The cable jacket shall not exhibit evidence of cracking or splitting.

The finished cable shall withstand a tensile load of 600 lbfs without exhibiting an average increase in attenuation of greater than 0.20 dB. The test shall be conducted in accordance with EIA-455-33 (FOTP-33), "Fiber Optic Cable Tensile Loading and Bending Test." The load shall be applied for one-half hour in Test Condition II of the EIA-455-33 (FOTP-33) procedure.

PACKAGING AND SHIPPING REQUIREMENTS.--Documentation of compliance to the required specifications shall be provided to the Engineer prior to ordering the material.

Attention is directed to "Fiber Optic Testing," elsewhere in these special provisions.

The completed cable shall be packaged for shipment on reels. The cable shall be wrapped in a weather and temperature resistant covering. Both ends of the cable shall be sealed to prevent the ingress of moisture.

Each end of the cable shall be securely fastened to the reel to prevent the cable from coming loose during transit. Two meters of cable length on each end of the cable shall be accessible for testing.

Each cable reel shall have a durable weatherproof label or tag showing the manufacturer's name, the cable type, the actual length of cable on the reel, the Contractor's name, the contract number, and the reel number. A shipping record shall be provided to the Engineer in a weatherproof envelope showing the above information and also include the date of manufacture, cable characteristics (size, attenuation, bandwidth, etc.), factory test results, cable identification number and any other pertinent information.

The minimum hub diameter of the reel shall be at least thirty times the diameter of the cable. The F/O cable shall be in one continuous length per reel with no factory splices in the fiber. Each reel shall be marked to indicate the direction the reel should be rolled to prevent loosening of the cable.

Installation procedures and technical support information shall be furnished at the time of delivery.

10-3.__ FIBER CABLE INSTALLATION

Fiber optic cable shall be installed in conduit system as show on the plans. Fiber optic conduit system shall consist of conduits, fiber optic pull boxes and fiber optic splice vaults or cabinets.

Installation procedures shall be in conformance with the procedures specified by the cable manufacturer for the specific cable being installed. The Contractor shall submit to the engineer the manufacturer's recommended procedures for pulling fiber optic cable at least 20 working days prior to installing cable. Mechanical aids may be used, provided that a tension measuring device is placed in tension to the end of the cable. The tension applied shall not exceed 500 lb-force or the manufacturers recommended pulling tension, whichever is less.

The F/O cable shall be installed using a cable pulling lubricant recommended by the cable manufacture and a non-abrasive pull tape conforming to the provisions described under "Conduit" elsewhere in these special provisions. Contractor's personnel shall be stationed at each pull box, vault and cabinet through which the cable is pulled to lubricate and prevent kinking or other damage.

During cable installation, the bend radius shall be maintained at not less than twenty times the outside diameter of the cable. .The cable grips for installing the fiber optic cable shall have a ball bearing swivel to prevent the cable from twisting during installation.

At the Contractor's option, the fiber cable may be installed using the air blown method. If integral innerduct is used, the duct splice points or any temporary splices of innerduct used for installation must withstand a static air pressure of 110 psi.

6

The fiber installation equipment must incorporate a mechanical drive unit or pusher, which feeds cable into the pressurized innerduct to provide a sufficient push force on the cable, which is coupled with the drag force created by the high-speed airflow. The unit must be equipped with controls to regulate the flow rate of compressed air entering the duct and any hydraulic or pneumatic pressure applied to the cable. It must accommodate longitudinally ribbed or smooth wall ducts from nominal 0.625-inch to 2-inch inner diameter. Mid assist or cascading of equipment must be for the installation of long cable runs. The equipment must incorporate safety shutoff valves to disable the system in the event of sudden changes in pneumatic or hydraulic pressure.

7

The equipment must not require the use of a piston or any other air capturing device to impose a pulling force at the front end of the cable, which also significantly restricts the free flow of air through the inner duct. It must incorporate the use of a counting device to determine the speed of the cable during installation and the length of the cable installed.

The cable shall be installed without splices except where specifically allowed on the plans or described in these special provisions. Minimum slack of the cable as shown on the plans shall be provided at each cable access location without a cable splice. At fiber optic splice location, a minimum of 30 feet slack of each cable shall be stored in the splice location.

10-3.__ COLORED CONCRETE BACKFILL

The concrete backfill for the installation of fiber optic conduits in trench shall be a medium to dark, red color to clearly distinguish the concrete backfill from other concrete and soil. The concrete shall be pigmented by the addition of commercial quality cement pigment to the concrete mix. The red concrete pigment shall be LM Scofield Company; Orange Chromix Colorant; Davis Colors; or equal. The concrete shall conform to the provisions in said Section 90-10, "Minor Concrete."

For trenches in pavement areas, only the top 4 inch of concrete backfill will be required to be pigmented concrete. At the option of the Contractor, the full depth may have the pigment.

10-3.__ FIBER OPTIC PULL BOX

Each fiber optic pull box shall conform to Section 86-2.06, "Pull Boxes," of the Standard Specifications for type 6 with extensions and as shown on the plans.. Cover marking shall be "CALTRANS TOS COMMUNICATION" on the cover. Pull box cover and extensions may be constructed of reinforced portland cement concrete or of non-PCC material with concrete gray color.

Conduits shall enter the fiber optic pull box through the sidewall at not more than 6 inches from the bottom of the pull box.. Conduits shall not enter through the bottom of the pull box. Conduits shall not protrude more than 2 inches inside the pull box and shall enter the pull box at about 20 degrees in both the vertical and horizontal directions. Watertight sealing plugs as specified elsewhere in this special provisions are required around all conduits.

10-3.__ FIBER OPTIC VAULT

Fiber optic vaults shall be 52" (L) x 34" (W) x 24" (D) nominal inside dimensions and shall conform to Section 86-2.06, "Pull Boxes," of the Standard Specifications. Covers shall be in one or two sections. Hold down bolts or cap screws and nuts shall be of brass, stainless steel or other non-corroding metal material. Each cover portion shall have inset lifting pull slots. Cover marking shall be "CALTRANS TOS COMMUNICATION" on the cover. Vault, cover and extensions may be constructed of reinforced portland cement concrete or of non-PCC material with concrete gray color.

Non-PCC vaults and covers shall be of sufficient rigidity that when a 100 lb concentrated point force is applied perpendicularly to the midpoint of one of the long sides at the top while the opposite long side is supported by a rigid surface, it shall be possible to remove the cover without the use of tools. When a vertical force of 1500 lb is applied, through a 0.5" x 3" x 6" steel plate, to a non-PCC cover in place on a splice vault, the cover shall not fail and shall not deflect more than 0.25".

Fiber optic vaults shall be installed as detailed and as shown on the plans. All fiber optic vaults and covers shall have an AASHTO HS 20-44 rating. Fiber optic vaults shall be installed at grade. Metallic or non-metallic cable racks shall be installed on the interior of both long sides of the fiber optic vaults. The racks shall be capable of supporting a load of 100 lb, minimum, per rack arm. Racks shall be supplied in lengths appropriate to the box in which they will be placed. All metallic cable racks shall be fabricated from ASTM Designation: A36 steel plate and shall be hot-dip galvanized after fabrication. Steel plate, hardware and galvanizing shall be in accordance with the requirements of Section 75, "Miscellaneous Metal," of the Standard Specifications. Metallic cable racks shall be bonded and grounded.

Unless otherwise shown on the plans or as directed by the engineer, vaults shall be located outside the pavement with the lid centerline 5 feet from the edge of the pavement or back of the dike. Vaults may be moved farther from the roadway to accommodate buried objects, existing conduits, or similar items that prevent installation 5 feet from the pavement, but no part of the vault, concrete encasement ring, or backfill material shall be less than 18 inches from the edge of the pavement or back of the dike, to allow for future electrical conduit installations between the vault and roadway. The top of the vault lid shall match the final grade within 1 inch +/-0.5 inch.

Some locations along the roadway may have existing conduits, pipes, or drains parallel to the roadway and next to the shoulder, which may make it impossible to route conduits to the vault. At other locations, buried objects, steep drop-offs, or other object may make installation of a vault outside the pavement impossible. At these locations or as directed by the engineer, vaults may be installed in the pavement of the shoulder or in the pavement of chain on/off areas. Vaults placed inside the pavement shall be installed with the centerline of the vault not more 3 feet from the edge of pavement or back of dike, and with the entire top of vault lid 0.1 inch +/- 0.05 inch below the surface of the pavement, when all pavement work specified in the job is completed.

Vaults located at bridges where exposed conduit must be used, such as at undercrossings, shall be located as close as possible to the end of the structure unless otherwise specified on the plans, If not specified otherwise in the plans, the location of vaults at bridge structures shall be between the first and second guardrail posts. Unless otherwise directed by the engineer, the top of the vault lid at these locations shall be located entirely behind the guardrail and shall conform to the final grade of the surrounding fill at the vault location. No part of the vault or vault lid shall be exposed or extend past the edge of the hinge point for the bridge, or otherwise deform the earth fill at the vault location.

Conduits shall enter the fiber optic vault through the sidewall at not more than 6 inches from the bottom of the vault.. Conduits shall not enter through the bottom of the vault. Conduits shall not protrude more than 2 inches inside the pull box and shall enter the vault at about 20 degrees in both the vertical and horizontal directions. Watertight sealing plugs as specified elsewhere in this special provisions are required around all conduits.

10-3.__ CONDUIT SEALING PLUGS

Except otherwise noted, all fiber optic conduits shall have their ends sealed with commercial preformed plugs which prevent the passage of gas, dust and water into these conduits.

Sealing plugs shall be removable and reusable. Plugs shall be the split type that permits installation or removal without removing cables. Sealing plugs shall seal the conduit simultaneously with one self contained assembly having an adjustable resilient filler of neoprene or silicone rubber clamped between backing ends and compressed with stainless steel hardware.

To provide suitable sealing between future varying size cables and the plugs, split neoprene or silicone adapting sleeves, used singularly or in multiples, shall be inserted within the body of the plugs. Sealing plugs used to seal the fiber optic conduit shall be capable of withstanding a pressure of 5 psi. A sealing plug that seals an empty conduit shall have an eye or other type of capturing device (on the side of the plug that enters the conduit) to attach onto the pull rope, so that the pull rope will be easily accessible when the plug is removed.

10-3.__ WARNING TAPE

Warning tape must be furnished, installed and placed in the trench over new conduits to receive new fiber optic cable as shown on in the plans.

The warning tape must have:

DESCRIPTION	PARAMETERS
Thickness	not be less than 0.1 mm thick
Width	4 inches
Material	Orange color polyolefin film
Tensile strength	Minimum of 160 lb force
Elongation	minimum of 700 percent elongation before breakage
Printed Text height	1 inch black color
Message background color	bright orange color background
Message statement	CAUTION: BURIED FIBER OPTIC CABLE - CALTRANS RADIO ROOM (510) 286-6359
Message spacing intervals	approximately every 3 feet

The printed warning must not be removed by the normal handling and burial of the tape and must be rated to last the service life of the tape.

The construction of the warning tape must be such that it will not delaminate when it is wet. It must be resistant to insects, acid, alkaline and other corrosive elements in the soil.

Full compensation for furnishing and installing the warning tape must be considered as included in the contract lump sum price paid for Traffic Operations System and no additional compensation will be allowed therefore.

10-3.__ CABLE MARKER

Cable markers shall be provided at 50 feet spacing in places where fiber optic conduit is placed in non-paved areas. These markers shall conform to Standard Plan A73C, Class 1, Type F, flexible post delineators, except that the marker shall be non-reflective. The following text shall be written on each marker: "WARNING, FIBER OPTIC CABLE, call 72 Hours before You Dig, 1-510-286-4444, COMMUNICATIONS". See details on the plans.

10-3.__ TRUNKLING SPLICE CABINET

The trunkline splice cabinet (TSC) shall be a Type P cabinet. The Contractor shall construct each TSC foundation as shown on Standard Plan ES-4B including furnishing and installing anchor bolts, shall install the cabinet on the foundation, shall furnish and install fiber optic splice closure, cable retainer and shall make all cable breakout and field splice connections in the cabinet as shown on plans.

10-3.__ CABLE SPLICING

Field cable splices shall be done either in splice vaults or in cabinets as shown on the plans.

Unless otherwise allowed, the cable splices shall be fusion type. The mean splice loss shall not exceed 0.07 dB per splice. The mean splice loss shall be obtained by measuring the loss through the splice in both directions and then averaging the resultant values.

The mid-span access method shall be used to access the individual fibers in a cable for splicing to another cable as shown on the plans. Cable manufacturers recommended procedures and approved tools shall be used when performing a mid-span access. Only the fibers to be spliced may be cut. All measures shall be taken to avoid damaging buffer tubes and individual fibers including those not being used in the mid-span access.

The field splices shall connect the fibers of the two cable lengths together. These splices shall be placed in splice trays and these splice trays shall then be placed in the splice enclosure.

The termination splices shall connect the cable span ends with pigtails. The termination splices shall be placed in splice trays and the splice trays shall then be placed in the fiber distribution unit (FDU).

Splice trays must accommodate a minimum of 12 fusion splices. The individual fibers shall be looped at least one full turn within the splice tray to avoid micro bending. A 2 inches minimum bend radius shall be maintained during installation and after final assembly in the optical fiber splice tray. Each bare fiber shall be individually restrained in a splice tray. The optical fibers in buffer tubes and the placement of the bare optical fibers in the splice tray shall be such that there is no discernable tensile force on the optical fiber.

All splices shall be protected with a metal reinforced thermal shrink sleeve.

10-3.__ FIBER OPTIC SPLICE ENCLOSURE

Fiber optic cable field splices shall be enclosed in splice enclosures which shall be waterproof, rodent proof and re-enterable. The fiber optic splice enclosure shall be suitable for a temperature range of 0°C to 50°C.

The fiber optic splice enclosure shall consist of an outer closure, an inner closure and complete with splice organizer trays, brackets, plugs, clips, cable ties and sealants as needed and shall conform to the following special provisions.

The size of the enclosure shall allow all the fibers of the largest fiber optic trunk cable or buffer tube to be spliced to a second cable or buffer tube of the same size, plus fibers from fiber optic pigtail cable. The enclosure shall be not more than 36 inches in length and not more than 8 inches in diameter.

All materials in the enclosures shall be nonreactive and shall not support galvanic cell action. The outer-closure shall be compatible with the other closure components, the inner closure, splice trays, and cables.

The end plate shall consist of two sections and shall have capacity for two fiber optic trunk cables and fiber optic branch cables.

The outer-closure shall protect the splices from mechanical damage, shall provide strain relief for the cable, and shall be resistant to salt corrosion.

The outer-closure shall be waterproof, re-enterable and shall be sealed with a gasket. The outer-closure shall be flash-tested at 15 psi.

The inner-closure shall be of metallic construction. The inner-closure shall be compatible with the outer closure and the splice trays and shall allow access to and removal of individual splice trays. The splice trays shall be compatible with the inner closure and shall be constructed of rigid plastic or metal.

Adequate splice trays shall be provided to splice all fibers of the largest communication cable or buffer tube plus FPC in the splice cabinet.

Vinyl markers shall be used to identify each spliced fiber in the trays as described under "Fiber Optic Cable Labeling" elsewhere in these special provisions.

Each splice shall be individually mounted and mechanically protected in the splice tray.

The Contractor shall install the fiber splice enclosure in the splice vault or cabinet as shown on the plans where splicing is required. The Contractor shall provide all mounting hardware required to securely mount the fiber optic splice enclosures to the splice vault or cabinet.

The fiber splice enclosure shall be mounted as shown on the plans in a manner that allows the cables to enter at the end of the enclosure. Not less than 30 ft of each cable (2 or 3) shall be coiled in the splice vault or cabinet to allow the fiber splice enclosure to be removed for future splicing.

The unprotected fibers exposed for splicing within the enclosure shall be protected from mechanical damage using the fiber support tube or tubes and shall be secured within the fiber splice enclosure.

Upon completion of the splices, the splice trays shall be secured to the inner closure.

The enclosure shall be sealed using a procedure recommended by the manufacturer that will provide a waterproof environment for the splices. Encapsulant shall be injected between the inner and outer closures.

Care shall be taken at the cable entry points to ensure a tight salt resistant and waterproof seal is made which will not leak upon aging. It is not acceptable to have multiple cables enter the fiber splice enclosure through one hole.

10-3.__ FIBER OPTIC CABLE TERMINATIONS

DISTRIBUTION BREAKOUT.--The jacketed cable shall be lashed with tie wraps to the rack prior to entering the FDU. The cable shall also be tie-wrapped to the inside of the FDU near the point of entry. The glass fibers shall not be damaged during cutting and removal of the buffer tubes.

The jacketed area and bare fibers shall be cleaned to remove the moisture blocking gel. The transition from the buffer tube to the bundle of jacketed fibers shall be treated by an accepted procedure for sleeve tubing, shrink tubing and silicone blocking of the transition to prevent future gel leak. A subsequent transition shall be made, with flexible tubing, to isolate the fiber bundles of each buffer tube to serve as a transition from the bundle to the separation point and to protect the individual coated fibers. The last transition point (bundle to single fiber) shall consist of inserting the individual fibers into No. 26 AWG clear teflon tubing, to protect the fiber as it is routed toward the splice tray and to allow clear color identification of fibers for proper distribution. The final transition from bundle to individual fiber tube shall be secured with an adhesive heat shrink sleeve. The individual fibers shall then be stripped and prepared for splicing.

All fibers inside a fiber optic cable entering a FDU shall be properly terminated, whether they are used or not

DISTRIBUTION INTERCONNECT PACKAGE.--Distribution involves connecting the fibers to the active electronic components. The distribution equipment consists of FDUs with connector panels, couplers, splice trays, fiber optic pigtails and cable assemblies with connectors. The distribution interconnect package shall be assembled and tested by a company who is regularly engaged in the assembly of these packages. Attention is directed to "Fiber Optic Testing" elsewhere in these special provisions. All distribution components shall be products of the same manufacturers, who are regularly engaged in the production of these components, and the respective manufacturers shall have quality assurance programs.

10-3.__ FIBER OPTIC CABLE ASSEMBLIES AND PIGTAILS

General.--Cable assemblies and pigtails shall be products of the same manufacturer. The cable used for cable assemblies and pigtails shall be made of fiber meeting the performance requirements of these special provisions for the F/O cable being connected.

Pigtails.--Pigtails shall be of simplex (one fiber) construction, in 900 µm tight buffer form, surrounded by aramid for strength, with a PVC jacket with manufacturer identification information and a normal outer jacket with diameter of 0.12 inch. Singlemode cable jackets shall be yellow in color. All pigtails shall be factory terminated and tested and at least 3 feet in length.

Patch cords.—Patch cords may be of simplex or duplex design. Duplex jumpers shall be of duplex round cable construction, and shall not have zipcord (siamese) construction. The patch cord shall be terminated with ST compatible super physical contact singlemode connector at both ends. The fiber strands shall meet the specifications as those of the fiber cable and the connectors shall meet the specifications as specified elsewhere in these special provisions. All patch cords shall be at least 6 feet in length, sufficient to avoid stress and orderly routing.

The outer jacket of duplex patch cords shall be colored yellow. The two inner simplex jackets shall be color coded white and slate, respectively, to provide easy visual identification for polarity.

Connectors.--Connectors shall be of the ceramic ferrule ST "push-pull" type. Indoor ST connector housings shall be either nickel plated zinc or glass reinforced polymer construction. Outdoor connector body housing shall be glass reinforced polymer.

The associated coupler shall be same material as the connector housing.

All F/O connectors shall be 0.1 inch ST connector ferrule type with Zirconia Ceramic material with a physical contact pre-radiused tip.

The ST connector operating temperature range shall be from -40°C to +70°C. Insertion loss shall not exceed 0.4 dB and the return reflection loss on singlemode connectors shall be at least 40 dB. Connection durability shall be less than 0.2 dB change per 500 mating cycles per EIA-455-21A (FOTP-21). All terminations shall provide a minimum 50 lbforce pull out strength. Factory test results shall be documented and submitted to the Engineer prior to installing any of the connectors. Singlemode connectors shall have a yellow color on the body or the boot.

Field terminations shall be limited to splicing of adjoining cable ends or cables to ST pigtails.

ST Couplers.-The ST couplers shall be made of nickel plated zinc or glass reinforced polymer that is consistent with the material forming the associated ST connector body. The design mechanism for mounting the coupler to FDU connector module panel may be flanged or threaded but shall coincide with FDU panel punch-outs.

All coupler sleeves shall be ceramic of the split clamshell or clover leaf design.

The temperature range for the couplers shall be the same as that specified for the ST connectors.

10-3.__ FIBER OPTIC DISTRIBUTION UNIT

Fiber distribution unit (FDU) shall be EIA-310 standard mount type as shown on the plans.

FDU shall consist of a connector module housing (CMH) and a splice module housing (SMH). The CMH shall have sufficient number of connection panels to handle the associated fiber terminations. The SMH shall have the capacity to secure and store the required splice trays and break out cables.

Connector module housing (CMH) shall have a Lexan front cover so as not expose fiber optic connections. Each connection panel shall have six coupler capacity and all panel positions shall be filled with couplers. All spare couplers shall have dust covers on both sides. Each connection panel shall be secured to the CMH frame with two plastic puch snap fastener on each side of the panel.

Splice module housing (SMH) shall have sufficient number of splice trays to handle the transition splices between the field cables and their respective breakouts. Cable accesses to the SMH shall have grommets. SMH shall have a rear metal cover of the same gauge and color as the remainder of the FDU rack

The front and back covers of the FDU shall be retractable or removable to facilitate internal installation.

10-3.__ FIBER OPTIC LABELING

GENERAL

The Contractor shall label all fiber optic and copper communications cabling in a permanent consistent manner. All tags shall be of a material designed for long term permanent labeling of fiber optic and copper communications cables and shall be marked with permanent ink on non-metal types, or embossed lettering on metal tags. Metal tags shall be constructed of stainless steel. Non-metal label materials shall be approved by the Engineer. Labels shall be affixed to the cable per the manufacturer's recommendations and shall not be affixed in a manner which will cause damage to the fiber. Handwritten labels shall not be allowed.

LABEL IDENTIFICATION

Labeling of Cables.--Labeling of the backbone, distribution and drop fiber optic cables shall conform to the following unique identification code elements:

Labeling schemes

UNIQUE IDENTIFICATION CODE ELEMENTS FOR BACKBONE, DISTRIBUTION OR DROP CABLES

No.	DESCRIPTION	CODE	NUMBER OF CHARACTERS
1	Cable Type	Fiber: S: Singlemode	1
2	Fiber Count	Number of fibers or conductor pairs (example: 72 fibers)	3
3	Begin Function	T: TMC; H: Hub; V: Video Node; D: Data Node; C: Cable Node; TV: CCTV Camera; CM: CMS; E: Traffic Signal; RM: Ramp Meter; TM: Traffic Monitoring/Count Station/Vehicle Count Station (VDS, TMS); SV: Splice Vault SC: Splice Cabinet	1 or 2
4	County	County Number; Example: 033 (for Alameda)	3
5	Route Number	Hwy, Rte (example: 005)	3
6	Post Mile	Example: xxxxx	5
7	End Function	T: TMC; H: Hub; V: Video Node; D: Data Node; C: Cable Node; TV: CCTV Camera; CM: CMS; E: Traffic Signal; RM: Ramp Meter; TM: Traffic Monitoring/Count Station/Vehicle Count Station (VDS, TMS); SV: Splice Vault SC: Splice Cabinet	1 or 2
8	County	County Number; Example: 034 (for Sacramento)	3
9	Route Number	Hwy, Rte (example: 005)	3
10	Post Mile	Example: xxxxx	5
11	Unique ID	Identifies when two or more fiber cables are involved (example: xx)	2

Catrans District 4 county system numbers are as following:

County	County System Number
Alameda	33
Contra Costa	28
Marin	27
Napa	21
San Francisco	34
San Mateo	35
Santa Clara	37
Santa Cruz	36
Sonoma	20
Solano	23

Example: S 048 SV 033 080 00569 SV 033 080 00610 03.

The label in the example can be translated as a singlemode (S) 48 strand cable (048) that starts from a splice vault (SV) in Alameda County (033) on I-80 (080) post mile 5.69 (00569) ends at another splice vault (SV) in Alameda County (033) on I-80 (080) at postmile 6.10 (00610). This fiber optic cable is uniquely identified as 03. This means the cable is the 3rd of the fiber optic cables in the pull box or the vault.

Each cable shall display a unique identification, regardless of where the cable is viewed. The begin function and end function correspond to the end points of each cable. The order of the begin and end function follow a hierarchy as listed below, where the lowest number corresponding to the begin/end function is listed first.

1	TMC
2	HUB
3	Video Node (VN)
4	Data Node (DN)
5	Cable Node
6	CCTV Camera
7	CMS
8	Traffic Signal
9	Ramp Meter
10	Traffic Monitoring Count Station
11	HAR
12	EMS
13	Weather Station
14	Weight In Motion
15	Splice Vault or Cabinet

This scheme will work as follows:

A cable between the TMC and a HUB will always have the TMC listed as the start function and the HUB as the end function. Between a CMS and a Splice Vault, the start function will always be listed as the CMS, and so on. If a cable is connected between HUBs, for example HUB-01 and HUB-03, the lowest number, in this case HUB-01, will be listed as the start function and HUB-03 as the end function.

At each FDU or ITU the Contractor shall provide a listing of the cable or cables terminated and where each fiber appears on the connector panel, a list of all jumpers and the equipment that they are connected to, and a geographical layout of all the equipment installed by the Contractor. In field cabinets these shall be placed in a waterproof pouch mounted on the cabinet door.

LABEL PLACEMENT

Abbreviations:

TMC	TXXX.XX
HUB	HXXX.XX
VAULT	SVXXX.XX
PULL BOX	PBXXX.XX
CAMERA	TVXXX.XX
CMS	CMXXX.XX
TMS	TMXXX.XX
RAMP METER	RMXXX.XX
TRAFFIC SIGNAL	EXXX.XX
HAR	HRXXX.XX
EMS	FMXXX.XX
WEATHER STATION	WSXXX.XX
WEIGHT IN MOTION	WTXXX.XX

The X's denote the postmile of the above elements.

Cables.--All cables shall be clearly labeled with the unique identification code element method described elsewhere in these special provisions, at all terminations, even if no connections or splices are made, and at all splice vault entrance and exit points.

Cable to Cable Splices.--All cable jackets entering the splice enclosure shall be labeled in accordance with the identification method described elsewhere in these special provisions.

Cable to Fiber Distribution Units.--The cable jackets shall be clearly labeled at entry to the FDU in accordance with the unique identification code element method described elsewhere in these special provisions. In addition, each fiber and pigtail shall be labeled at the connector with the Fiber ID . The FDU shall be clearly labeled with the Cable ID on the face of the FDU. If multiple cables are connected to the FDU, each block of connectors relating to each individual cable shall be clearly identified by a single label with the Cable ID. Individual connections shall be clearly marked on the face of the FDU in the designated area with the Fiber ID.

Fiber.--Fibers labels shall be placed next to the connectors of the individual fibers.

Patch Panels.--The cable jackets shall be clearly labeled at entry to the Patch Panel in accordance with the unique identification code element method described elsewhere in these special provisions. In addition, each fiber and pigtail shall be labeled at the connector with the Fiber ID. . The Patch panel shall be clearly labeled with the Cable ID on the face of the Panel. If multiple cables are connected to the Patch Panel, each block of connectors relating to each individual cable shall be clearly identified by a single label with the Cable ID. Individual connections shall be clearly marked on the face of the Panel in the designated area with the Fiber ID.

Splice Trays.--A label shall be placed on each splice tray explaining the splices in each tray.

10-3.__ FIBER OPTIC TRANSMITTERS AND RECEIVERS

GENERAL

When fiber optic transmitters (FOTS) are connected to fiber optic receivers (FORS) via a fiber optic link, they shall support a minimum optical loss budget of 14 dB including system margin over a single mode fiber. The data channels shall be multiplexed and transmitted digitally with the video channel. The data channels shall support EIA-232 full duplex with data rate capability up to 9.6 kbps. The units shall use PFM, FM, FDM, FSK and digital techniques. The result shall be high quality, crosstalk free, adjustment free operation over a wide dynamic range. There shall be no variations in the video output level due to fiber attenuation, variation because of LED aging, optical "slip rings", dynamic cable layout, or environmental factors. The units shall be optimized for single-mode 8.3/125 µm fiber operating in the 1300 nm optical window. The optical connectors shall be of the ST-compatible type.

Each transmitter and receiver shall have sync and loop back indicators in its front face panel for visual verification of bi-directional operation.

PERFORMANCE REQUIREMENTS

The baseband video signal output from the video/data receivers when it is receiving an optical signal from the video/data transmitters at an average power level equal to the video/data receiver sensitivity shall meet the following performance specifications defined and measured in accordance with EIA-250 for Short Haul Transmission System for End-to-End modified performance.

Output Signal Level	as per EIA- 250
Amplitude Vs Frequency Characteristics	as per EIA- 250
Chrominance to Luminance Gain Inequality	as per EIA- 250
Chrominance to Luminance Delay Inequality	as per EIA- 250
Field Time Waveform Distortion	as per EIA- 250
Line Time Waveform Distortion	as per EIA- 250
Insertion Gain Variation	as per EIA- 250
Differential Gain	as per EIA- 250
Differential Phase	±2 degrees
Signal-to-noise ratio	50 dB weighted
Signal-to-low frequency noise ratio	as per EIA- 250

PHYSICAL AND MECHANICAL REQUIREMENTS

Each FOTS shall have the capability of transmitting one simplex composite NTSC baseband video channel, three full duplex data channels and one bi-directional audio channel over a single-mode optical fiber. Each FOTS shall accept a composite NTSC video input as well as provide input/output for full duplex data and audio. The FOTS shall utilize cooled 1300 nm laser diodes with at least -14 dBm and the spectral line width of less than or equal to 5 nm.

Each FOTS shall have the following interfaces/provisions:

1. The video interface that shall be via a BNC connector.
2. Data channel interface that shall be via an 8-position, 8-connector modular jack (RJ45).

3. n audio interface port compatible with unbalanced and balanced 0 dBm, 600 Ω, 4 wire line. The audio interface shall be via an 8-position , 8-connection modular jack (RJ45).
4. handset port compatible with standard telephone set equipped with carbon microphone. The handset port shall consist of a 4-position, 4-connection modular jack.

Each FORS shall have the capability of receiving one simplex composite NTSC baseband video channel, three full duplex data channels and one bi-directional audio channel from a single-mode optical fiber. Each FORS shall provide a composite NTSC video output as well as provide input/output for full duplex data and audio.

Each FORS shall have the following interfaces/provisions:

1. Video interface that shall be via a BNC connector.
2. Data interface that shall be via an 8-position, 8-connector modular jack (RJ45).
3. A harness with the modular jacks and screw terminal connectors for the audio and data signals. .The harness shall be fully compatible with the FDU and FORS as specified in these special provisions.

The I/O for each FORS shall correspond to the following configuration on the RJ45 jack of the harness. Single ended or differential transmission shall be selected by DIP-switches on the FORS.

RJ45 CONTACTS	EIA-232	EIA-422
1	NC	NC
2	CTRL OUT	NC
3	TxD	TxD-
4	RxD	RxD-
5	GND	RxD+
6	GND	TxD+
7	CTRL IN	NC
8	NC	NC

3. Each FORS shall provide an audio interface port compatible with unbalanced and balanced 0 dBm, 600 Ω, 4 wire line. The audio interface shall be via an 8-position , 8-connection modular jack (RJ45).
4. Each FORS shall provide a handset port compatible with standard telephone set equipped with carbon microphone. The handset port shall consist of a 4-position, 4-connection modular jack and shall be located on the front panel of each FORS.

Each FOTS and FORS shall be housed in a compact stand-alone enclosure with side flanges and shall be shelf mountable.

Each FOTS and FORS shall be powered by unregulated +12 V(dc) at 370 to 480 mA. An AC to DC wall mount adapter may be used for powering from 120 V(ac), 60 Hz.

ENVIRONMENTAL REQUIREMENTS

Each FOTS and FORS shall be fully operational over a temperature range of -30°C. to +70°C. and shall withstand a humidity range from 0 to 95 percent without condensation.

10-3.__ FIBER OPTIC DATA MODEM

The fiber optic data modem (FODM) shall be RS-232 compatible fiber optic modem with dual optics for drop/insert capability which can be configured as master or local(slave) in either daisy chain or fault tolerant dual redundant (counter rotating) ring network architecture. These four modes of operations shall be selectable via an external Mode DIP-switch. All signals received via an optical port and retransmitted via fiber or via an expansion port shall be retimed to 0.01 percent pulse width accuracy by a crystal controlled timebase, eliminating pulse width distortion and eliminating virtually unlimited repeating. The FODMs shall have anti-streaming circuitry for both the optical fiber and the electrical (RS-232) sides. On RS-232 side, when enabled, the anti-streaming shall limit the amount of time an external device is allowed to transmit data onto the network for each Request to Send (poll). On the fiber side, the anti-streaming shall disable an optical receiver in the event that the receiver output stays high longer than maximum allowable time thus preventing the whole fiber network from being disabled by a continuous "on" failure by receiver or optical emitter. External (TIMEOUT) DIP-switch shall allow user to disable or select the timeouts for both the optical side anti-streaming feature and the RS-232 side anti-streaming feature as well as to enable or disable the "Fiber Activity CTS Disable" feature. LED indicators to display power "on", anti-streaming "Fault" time-out and RS-232 fiber optic activity (selectable via dual function switch).

The FODMs at the field element shall be stand-alone type and shall be securely fastened on a EIA-310 rack-mount shelf. At the hub location, the FODMs shall be rack-mount type installed in card cage assembly. The card cage assembly shall be EIA-310 rack mount type with at least 14 slots and with two power supplies for redundancy.

The FODM shall meet the following requirements:

Electrical Signaling:	EIA RS-232 with full handshake control signals
Electrical Power:	115 V(ac), 60 Hz
Operating Temperature	-40 to 70°C
Operating Mode:	1. Daisy chain Master mode 2. Daisy chain Local mode 3. Fault tolerant Master mode 4. Fault tolerant Local mode
Emitter type:	Laser
Wavelength	1310 nm
Minimum coupled transmit power into: 9/125µm at 25°C(75°C)	-11(-9.5) dBm
Output Variation	-0.015 dB/°C
Minimum receiver input power for 10^{-9} BER	-40 dBm
Maximum receiver input	-11 dBm
Optical port type	ST
RS-232 connector type	DB25 female
Data Rates (auto)	1200 baud to 57.6 kbaud
Bit Error Rate:	10^{-9}
Link Budget(Range) via singlemode 1310 nm	31 dB for (56 km)

FODMs shall be tested as follows:

Each optical modem shall be functionally tested by looping back optical transmit connector to the optical receive connector using a variable optical attenuator with measured optical loss at 31 dB at 1310 nm. A test set shall be connected to the modem and set for RS-232 communication testing. Fifteen minutes BER test burn-in test shall be error free.

After performing the 15 minutes BER test, at least two modems shall be tested for receiver dynamic range. The following procedure shall be followed: First, the optical attenuation shall be increased to the point at which the data test just begins to register bit errors. The optical receive power into the modem shall be measured and recorded. The optical atttenuation shall be then decreased until data test once again register errors. At no time shall the optical power into the receiver exceed the manufacturer's specified saturation level. The optical receive levels shall once again be measured and recorded. These minimum and maximum receiver power levels define modem receiver's dynamic range and shall meet or exceed the manufacturer's specifications.

One pair of modem shall be interconnected using optical patch cords and attenuators with a loss of 31 dB in each direction. The RS-232 interface shall be looped back onto one modem and a test set connected to the RS-232 interface of the other modem. A bit error rate of less than 10^{-9} shall be demonstrated.

10-3.__ HUB EQUIPMENT

Hub equipment shall conform to all rules and regulations of the Federal Communications Commission (FCC) in addition to the provisions in Section 86, "Signals, Lighting and Electrical Systems," of the Standard Specifications and these special provisions.

Prototype equipment is not acceptable. All equipment shall be current standard production units and shall have been in use for a minimum of 6 months. Rebuilt or reconditioned equipment will not be allowed. All rack mounted equipment and card cage assemblies shall have metal filler plates to cover any unused channel slots or card slots.

The communication equipment shall include associated power supplies and interconnect cables.

The communication equipment shall be designed for testing, monitoring, and adjustment without service interruption.

Front access shall be provided for all routine adjustments normally required to be performed by field personnel.

The Contractor shall install hub equipment with the following equipment, associated cable connectors and other necessary components for a functional and fully integrated system:

1 - Fiber multiplexer and access unit (FMAU) - (State-furnished).
1 - Master traffic control unit (MTCU).
1 - Switch ethernet hub.
4 - Fiber optic data modems (FODM) with 1- Card cage assembly with power supply.
1 - Video and PTZ control data matrix switch system.
4 - Video encoder units (VEU).
2 - Fiber distribution units (FDU) - (described elsewhere in these special provisions).
2 - Fiber storage enclosures (FSE) - (described elsewhere in these special provisions).
19 - Video receiver duplex data (VRDD) units with 3 - Card cage assemblies with power supplies.
9 - Power strips.

The hub location is shown on the plans.

10-3.__ FIBER OPTIC TESTING

GENERAL

Testing shall include the tests on elements of the passive fiber optic components: (1) at the factory, (2) after delivery to the project site but prior to installation, (3) after installation but prior to connection to any other portion of the system, and (4) during final system testing. The active components shall be tested after installation. The Contractor shall provide all personnel, equipment, instrumentation and materials necessary to perform all testing. The Engineer shall be notified two working days prior to all field tests. The notification shall include the exact location or portion of the system to be tested.

Documentation of all test results shall be provided to the Engineer within 5 working days after the test involved. The Contractors attention is directed to "As-Built Plans" elsewhere in these special provisions, regarding the requirements for recording test results.

A minimum of 15 working days prior to arrival of the cable at the site, the Contractor shall provide detailed test procedures for all field testing for the Engineer's review and approval. The procedures shall include the tests involved and how the tests are to be conducted. Included in the test procedures shall be the model, manufacturer, configuration, date and operating procedures.

FACTORY TESTING

Documentation of compliance with the fiber specifications as listed in the Fiber Characteristics Table shall be supplied by the original manufacturer. Before shipment, but while on the shipping reel, 100 percent of all fibers shall be tested for attenuation. Copies of the results shall be (1) maintained on file by the manufacturer with a file identification number for a minimum of seven years, (2) attached to the cable reel in a waterproof pouch, and (3) submitted to the Contractor and to the Engineer.

ARRIVAL ON SITE

The cable and reel shall be physically inspected on delivery and 100 percent of the fibers shall be attenuation tested to confirm that the cable meets requirements. Attenuation tests shall be performed with an OTDR capable of recording and displaying anomalies of 0.02 dB as a minimum. Singlemode fibers (SM) shall be tested at 1310 nm and at 1550 nm. Test results shall be recorded, dated, compared and filed with the copy accompanying the shipping reel in a weather proof envelope. Attenuation deviations from the shipping records greater than 5 percent shall be brought to the attention of the Engineer. The cable shall not be installed until completion of this test sequence and the Engineer provides written approval. Copies of traces and test results shall be submitted to the Engineer. If the test results are unsatisfactory, the reel of FO cable shall be considered unacceptable and all records corresponding to that reel of cable shall be marked accordingly. The unsatisfactory reels of cable shall be replaced with new reels of cable at the Contractor's expense. The new reels of cable shall then be tested to demonstrate acceptability. Copies of the test results shall be submitted to the Engineer.

AFTER CABLE INSTALLATION

After the fiber optic cable has been pulled but before breakout and termination, 100 percent of all the fibers shall be tested with an OTDR for attenuation. Test results shall be recorded, dated, compared and filed with the previous copies of these tests. Copies of traces and test results shall be submitted to the Engineer. If the OTDR test results are unsatisfactory, the fiber optic cable segment will be unacceptable. The unsatisfactory segment of cable shall be replaced with a new segment, without additional splices, at the Contractor's expense. The new segment of cable shall then be tested to demonstrate acceptability. Copies of the test results shall be submitted to the Engineer.

Attenuation tests shall be performed with an OTDR capable of recording and displaying anomalies of 0.02 dB as a minimum. Singlemode fibers (SM) shall be tested at 1310 nm and at

1550 nm. Attenuation readings shall be recorded on a cable data sheet showing factory and after installation results.

The OTDR shall have a printer capable of producing a verifying test trace with fiber identification as shown in Appendix A "Link Loss Budget Work Sheet," numerical loss values, the date and the operator's name. It shall also have a DOS based 3.5" disk recording capability that has associated software to do comparisons and reproductions on 8.5" x 11" paper, via a personal computer.

FIBER OPTIC SYSTEM GAIN MARGIN

The installed system gain margin shall be at least 6 dB for each and every link. If the design system gain margin is less than 6 dB, the Engineer shall be notified and informed of the Contractor's plan to meet that requirement. Test results shall be recorded and submitted to the Engineer for approval..

INTERCONNECTING PARTS TESTING AND DOCUMENTATION

All the components of the passive interconnecting parts (FDUs, pigtails, couplers and splice trays) shall be from a manufacturer who is regularly engaged in the production of the fiber optic components described.

Each ST termination shall be tested for insertion attenuation loss with the use of an optical power meter and source. In addition, all singlemode terminations shall be tested for return reflection loss. These values shall meet the loss requirements specified earlier and shall be recorded on a tag attached to the pigtail or jumper.

Once interconnecting assembly is complete, the contractor shall visually verify that all tagging, including loss values, is complete. Then as a final quality control measure, the contractor shall do an "end to end" optical power meter/light source test from pigtail end to jumper lead end to assure continuity and overall attenuation loss values.

The final test results shall be recorded, along with previous individual component values, on a special form assigned to each FDU. The completed form shall be dated and signed by the contractor's supervisor. One copy of this form will be attached in a plastic envelope to the assembled FDU unit. Copies will be provided separately to the Contractor and to the Engineer.

ACTIVE COMPONENT TESTING

The transmitters and receivers shall be tested with a power meter and light source, to record the transmitter average output power in (dBm) and receiver sensitivity in (dBm). These values shall be recorded in the "Link Loss Budget Work Sheet" shown in Appendix A.

SYSTEM VERIFICATION AT COMPLETION

Once the passive cabling system has been installed and is ready for activation, 100 percent of the fiber links shall be tested with the OTDR for attenuation at both wavelengths. Test results shall be recorded, dated, compared and filed with previous copies. A hard copy printout and a electronic copy of the traces and test results along with a licensed copy of the associated software on a minimun 4 GB USB version 2.0 flash drive or a Secure Digital card shall be submitted to the Engineer. If the OTDR test results are unsatisfactory the link shall be replaced at the Contractor's expense. The new link shall then be tested to demonstrate acceptability. Copies of the test results shall be submitted to the Engineer.

The "Link Loss Budget Work Sheet" shown in Appendix A shall be completed for each link in the fiber optic system, using the data gathered throughout the installation process. The completed work sheets shall be included as part of the system documentation in the As-Built Plans.

The "Total System Gain" shall be calculated by subtracting the measured "Optical Receiver Sensitivity" (line 1B on the "Link Loss Budget Work Sheet") from the measured "Optical Transmitter Average Power" (line 1A), which were obtained using a power meter and source. The resulting difference shall be the maximum allowable loss between the transmitter and the receiver, within 0 percent to +10 percent of the manufacturers specified loss budget for the transmitter/receiver pair. The "Total System Gain" shall be recorded on line 1C.

The "Fiber Losses" for a link shall be calculated by multiplying the length of the fiber link (line 2A) by the normalized cable attenuation (dB/km, line 2B) at the operating wavelength. The normalized attenuation for this calculation shall be the maximum value throughout the operating temperature range of the cable. The product shall be recorded on line 2C.

The total connector losses shall be calculated by summing the individual attenuation values for each connector pair in the link, excluding the transmitter and receiver connectors. The sum shall be recorded on line 2D.

The total splice losses shall be calculated by summing the individual attenuation values for each splice in the link. The sum shall be recorded on line 2E.

The total of other losses shall be calculated by summing the individual attenuation values for each component in the link not previously addressed. The sum shall be recorded on line 2F. These items may include, but are not limited to, couplers, splitters, routers and switches.

The "Total System Loss" shall be recorded on line 2G of the "Link Loss Budget Work Sheet."

The "Design System Gain Margin" shall be calculated by subtracting the Total System Loss (line 2G) from the Total System Gain (line 1C). The resulting difference shall be recorded on line 3A. The Contractor's attention is directed to "F/O System Gain Margin," elsewhere in these special provisions.

At the conclusion of the final OTDR testing, 100 percent of all fiber links shall be tested end to end with a power meter and light source, in accordance with EIA Optical Test Procedure 171 and in the same wavelengths specified for the OTDR tests. These tests shall be conducted in both directions. Test results shall be recorded, compared and proven to be within the design link loss budgets, and filed with the other recordings of the same links. Test results shall be submitted to the Engineer.

If during any of these system verification tests, the results prove to be unsatisfactory, the F/O cable will not be accepted. The unsatisfactory segments of cable shall be replaced with a new segment of cable at the Contractor's expense. The new segment of cable shall undergo the same testing procedure to determine acceptability. Copies of the test results shall be submitted to the Engineer. The removal and replacement of a segment of cable shall be interpreted as the removal and replacement of a single contiguous length of cable connecting two splices, two connectors, or a splice and a connector. The removal of only the small section containing the failure and therefor introducing new unplanned splices, will not be allowed.

APPENDIX A

Link Loss Budget Worksheet

Contract No. __________

Contractor: ____________________

Approved by Caltrans: ___________

Date: ____________ Operator:_______________

Link Number: ___________ Fiber Color: ____________

Buffer Color: ___________ Cable #: ________________

Test Wavelength (Circle one): 1310 nm 1550 nm

Section 1: Total System Gain

Measured Optical Transmitter Average Power:	_________	dBm	1A
Measured Optical Receiver Sensitivity (this should be a negative value):	_________	dBm	1B
Subtract line 1B from 1A to obtain Total System Gain:	_________	dB	1C

Section 2: Total System Loss

Measured length of the link:	_________	km	2A
Measured loss per km of the fiber:	_________	dB/km	2B
Multiply line 2A by 2B to obtain the Total Fiber Loss:	_________	dB	2C
Sum of all Connector Losses in the link:	_________	dB	2D
Sum of all Splice Losses in the link:	_________	dB	2E
Sum of all Other Losses from other components (couplers, splitters, routers, switches, etc.)	_________	dB	2F
Add lines 2C, 2D, 2E and 2F to obtain Total System Loss:	_________	dB	2G

Section 3: Design System Gain Margin

Subtract line 2G from line 1C (This number must be at least 6 dB):	_________	dB	3A